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RESEARCH PROGRAMS

Project Summary Report: FHWA/MT-21/9578-606

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Feasibility of Non-Proprietary Ultra-High Performance Concrete (UHPC) For Use in Highway Bridges in Montana: *Phase II Field Application*

https://www.mdt.mt.gov/research/projects/mat/high_performance_concrete.shtml

Introduction

Ultra-high performance concrete (UHPC) has mechanical and durability properties that far exceed those of conventional concrete. However, using UHPC in conventional concrete applications can be cost prohibitive. Previous research conducted at Montana State University (MSU) resulted in non-proprietary UHPC mixes made with materials readily available in Montana. These mixes are significantly less expensive than commercially available UHPC mixes, thus opening the door for their use in construction projects in the state. The MDT Bridge Bureau is interested in using UHPC in field-cast joints between precast concrete deck panels. The use of UHPC in this application will reduce development lengths, and subsequently reduce the requisite spacing between the panels and improve the overall performance of the bridge. The second phase of research, discussed herein, builds on the non-proprietary UHPC research already completed, and focuses on ensuring the successful application of this material in these field-cast joints. This objective was achieved by (1) investigating the potential variability in concrete performance related to differences in constituent materials, (2) investigating issues related to the field batching/mixing of these UHPC mixes, and (3) testing rebar bond strength and studying how this will affect requisite development lengths.

What We Did

The objectives of this research were realized through the following tasks:

- A comprehensive literature review was conducted to evaluate the state-of-the-practice and recent advances in UHPC. In particular, this review focused on non-proprietary UHPC and the use of UHPC in field cast joints.
- The effects that variations in the materials (e.g., fly ash source, water reducer, steel fiber source, type, and source of sand) and material properties (e.g., aggregate moisture content and gradation) have on the performance of the UHPC were investigated.
- The effects of various mixing conditions (e.g., batch sizes, various temperatures, and aggregate moisture contents) were investigated. The mixer used in this investigation is shown in Figures 1, while Figure 2 shows UHPC being mixed in this mixer.

- The bond behavior of deformed reinforcing steel in the newly developed non-proprietary UHPC was characterized, and its effect on bar development lengths was investigated to confirm its performance in the proposed application. Specifically, the bond behavior was investigated by conducting direct tension pullout tests (Figure 3). In these tests, the effect of embedment length, concrete cover, bar spacing, and bar size were investigated.

Figure 1: Imer Mortarman mixer used for larger-scale mixes.

Figure 2: UHPC being mixed.

Figure 3: Bar pullout test setup.

What We Found

Based on this investigation, the following conclusions were made:

1. While variations in the source of the constituent materials (e.g., cement, fly ash, aggregate) had some effects on UHPC performance, the effects were fairly minor. Further, it should be noted that the same base mix design was used in all of the materials investigated in this research, and some of the differences in performance could be eliminated if the mix design was adjusted accordingly to account for the variations in the material.
2. As expected, the flow of the UHPC mixes generally increased with increasing aggregate moisture content, and the 7- and 28-day compressive strengths generally decreased. However, adjusting the mix water to account for the variations in aggregate moisture contents did not significantly affect the observed flow of the mixes, but generally did improve the observed compressive strengths.
3. The recommended MT UHPC mix demonstrated high early strengths, with compressive strengths of around 10 ksi at 24 hours. The mix continued to gain strength over time, ultimately reaching compressive strengths of around 20 ksi at 182 days. Figure 4 shows the strength gain profile of this material.
4. Batch size did not have a significant effect on flow or compressive strength; however, it was observed that the larger scale mixes used in this phase of research required 10% more water and HRWR to obtain the same performance observed for the smaller batches used in the material sensitivity study (when size was increased from 0.2 cu. ft. to 2.5 cu. ft. or larger).
5. Temperature was observed to influence several parameters. Specifically, flow was observed to decrease with increasing temperature, while the compressive strengths for the hot mix were consistently the lowest. These results indicate that care should be given while batching and mixing UHPC mixes at higher temperatures.
6. Regarding the pullout tests, all of the reinforcing bars that met the minimum FHWA recommendations for embedment depth and clear cover reached at least their yield stress prior to bond failure, indicating that the FHWA recommendations are suitable for use in connections made with the MT UHPC.
7. Finally, despite the wide range of mixing conditions studied in this phase of research, all mixes in this study had flows between 6 and 11 inches, and respective 7- and 28-day compressive strengths of at least 13 and 16 ksi. This consistent/adequate

performance under varying conditions indicates that the MT UHPC mix is suitable for field applications in Montana. However, trial batches should be performed to optimize performance and account for the variations in materials and mixing conditions.

What the Researchers Recommend

While this research explored/addressed many of the issues that may arise while using this non-proprietary UHPC in field-cast applications, an implementation project using UHPC in an actual bridge project in Montana should be pursued. Two bridges have already been identified for such a project (Trail Creek Bridges on Highway 43 West of Wisdom), and preliminary planning for using UHPC on these bridges has begun. The scope of this implementation project could include: (1) closing any minor research gaps that may prohibit UHPC use in the desired application, (2) the development of specifications for this material documenting mix proportions and batching/mixing instructions (3) working with the selected contractor to conduct and test several trial batches/pours/mockups to ensure proper mixing/curing/finishing procedures, (4) assisting contractor on bridge projects and preparing specimens on construction day for quality control tests, and (5) monitoring the performance of the deck after completion.

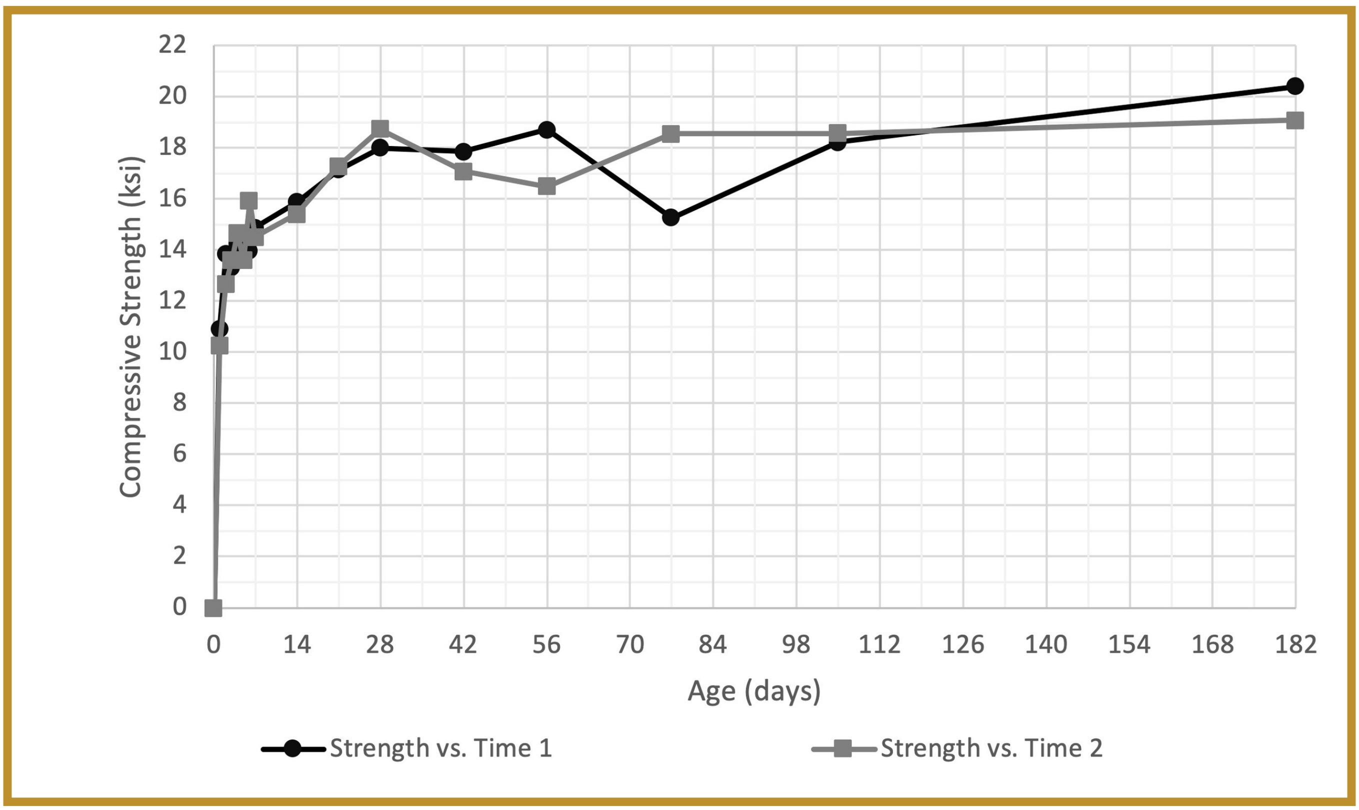

Figure 4: Strength gain profile.

For More Details . . .

The research is documented in Report FHWA/MT--21-002/9578-606, https://www.mdt.mt.gov/research/projects/mat/high_performance_concrete.shtml.

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To obtain copies of this report, contact MDT Research Programs, 2701 Prospect Avenue, PO Box 201001, Helena MT 59620-1001, mdtresearch@mt.gov, 406.444.6338.

MDT Implementation Status: June 2021

An implementation project is active. More information can be found atttps://www.mdt.mt.gov/research/projects/mat/high_performance_concrete.shtml. In addition, a related UHPC applications project is active; more informtion on this project can be found at https://www.mdt.mt.gov/research/projects/uhpc.shtml.